

CT-MPipe v1.5

Instruction and Reference Manual for CT-MPipe Program

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Summary of Revisions

Version 1.1

1. Updated BLRM equation callouts
2. Modified files names in the CT-MPipe Program folder
3. Fixed the units for the Dead Load and Live Load pressure equation to eliminate error when writing to the CT-MPipe Results file

Version 1.2

1. Updated the calculation for long span minimum cover, in Section 7, to handle errors and consider the limitations noted in BDS Article 12.8.3.1.

Version 1.3

1. Updated the CT-MPipe Program to consider the provisions of the AASHTO LRFD Bridge Design Specifications 8th edition.
2. Updated the CT-MPipe Program to consider the provisions of the AASHTO Manual for Bridge Evaluation 3rd edition.
3. Added the ability to analyze Underpass structures.
4. Removed the minimum height of cover requirement for computing rating factors. The worksheet will check if the height of cover is AASHTO compliant but will compute rating factors regardless of if this criterion is satisfied.
5. Revised Section 7 to include a live load distribution through fill check. The worksheet will check if the live load distribution through fill is AASHTO compliant but will compute rating factors regardless of if this criterion is satisfied.

Version 1.4

1. Revised the CT-MPipe_Start file to include a hyperlink to the CT-MPipe Instructions.
2. Minor format change to CT-MPipe_Start file.
3. Added the ability to analyze Low Profile (2-radii) Arch structures.
4. Revised the Arch-Tangent corrugation to replace the tangent angle input with a radius input, which will remain consistent with the corrugation size.
5. Clarified the corrugation thickness to be input as the uncoated thickness measurement.
6. Added additional output to display minimum and maximum depths of fill used for the analysis. Refer to Section 7 of the CT-MPipe worksheet.
7. Revised the secant soil modulus calculation to consider variable depths of fill.
8. Revised CT-MPipe instructions to provide additional clarification and modifications for above mentioned updates.

Version 1.5

1. Added the ability to analyze High Profile (3-radii) Arch structures.
2. Revised CT-MPipe instructions to provide additional clarification and modifications for above mentioned updates.

Introduction

The CT-MPipe Program is a Mathcad worksheet that calculates rating factors based on user-defined corrugated pipe properties. The CT-MPipe Program will require activation via the CT-MPipe_Start file, located in the CT-MPipe Program Package. The activation process will save a copy of the CT-MPipe Program and necessary data files (MPipe-References) to the users References File for the Bridge.

Program Activation and Instructions

1. To activate the CT-MPipe Program, open the CT-MPipe_Start file, located in the CT-MPipe Program Package
2. Populate all orange fields

FIELD NAME	DESCRIPTION
Structure No.	Enter the Structure Identification Number NBI item 8, maintain all leading zeros
Feature Carried	Enter the Feature Carried by Structure NBI item 7
Feature Crossed	Enter the Feature Crossed by Structure NBI item 6A
Town	Enter the City or Town NBI item 4 description
Prepared By	Enter the name of the engineer who performed the rating
Date Prepared	Enter the date the rating was performed
Organization	Enter the name of the company or organization who performed the rating
Culvert Span	Span length of culvert perpendicular to the flow line
Depth of Fill	Height of fill from the top of the culvert crown to the top of the pavement. To analyze multiple depths of fill, input each fill height separated by a comma (i.e., 2, 2.5, 3, 4)
Width of Culvert	Culvert run length parallel to the flow line
Average Daily Truck Traffic	The calculated average daily truck traffic for the structure
Apply Rigid Concrete Pavement Reduction	Option use to consider the rigid concrete pavement reduction factor, as discussed in BLRM Section 10.4

*Note: all orange fields must be populated prior to clicking the 'Start' button.

3. Click the 'Start' button. The 'Start' button will generate live load pressures, using the CT-Fill Program, open the CT-MPipe Mathcad worksheet for the additional inputs required for rating, and close the CT-MPipe_Start file.
4. Refresh the Mathcad worksheet to ensure all fields are updated. The 'Math Regions' in the worksheet are highlighted to alert the user of the type of input required. In addition to the colored regions, noted in Step 4, the worksheet contains orange text boxes, which prompt the user to "Expand this section" or "Collapse this section" for areas within the worksheet. These prompts are dependent on information previously inputted in the worksheet and will update automatically.

Yellow	Required user input
Blue	Optional user input
Red	Default user input *If a default value is modified, the LRE must provide documentation to justify the updated value.

5. Navigate through Sections 1 through 7 to verify and modify all user-defined inputs.
 - a. Sections 8 through 12 are reserved for various thrust and capacity calculations performed by the worksheet and do not contain required user inputs.
 - b. Sections 13 and 14 are reserved for rating factor calculations for the various failure mechanisms required for the load rating analysis of the structure.
6. Once all user-defined inputs are complete, the controlling rating factors for each vehicle are displayed in Section 14.
7. To view the detailed rating factor results, the user may access the CT-MPipe Results file in the MPipe-AppData folder.

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USER TIP

If the user would like to modify the fill heights after the initial analysis:

1. Close the Mathcad worksheet
2. Open the CT-MPipe_Start file
3. Modify input field
4. Click the 'Start' button

Mathcad User-Defined Input Definitions

Section 1 – File Path Definitions

The files paths, defined below, provide the Mathcad worksheet the ability to read the live load through fill data from the CT-Fill Program and write the results to the CT-MPipe Results file, contained in the MPipe-AppData folder.

ITEM	VARIABLE	DESCRIPTION
'CT-Fill' Program File Path	File	Local file path for the applicable CT-Fill Program. Used to read the live load crown pressures from CT-Fill Program.
'CT-MPipe Results' File Path	File _{write}	Local file path of the applicable CT-MPipe Results file. Used to write the results to the CT-MPipe Results file.

The following information is obtained from the CT-Fill Program:

ITEM	VARIABLE	DESCRIPTION
Span	Span	Culvert span length
Live loads	LiveLoad	An array of the vehicle names analyzed
Vehicle type	VehicleType	An array of the vehicle types analyzed
Live load factors	γ_{LL}	An array of the calculated live load factors for each vehicle
Live load crown pressure	P_{L_crown}	An array of the calculated live load crown pressure for each vehicle
Live load patch length at depth of fill	l_w	An array of the calculated patch length for each vehicle
Live load distribution factor	LLDF	An array of the live load distribution factor for each vehicle
Depth of fill	H_{fill}	An array of the fill depths analyzed
Tire patch width	w_t	An array of the tire patch width for each vehicle
List of vehicles analyzed	VehicleList	An array of the vehicle names from the Vehicles tab
List of vehicle types analyzed	VehicleTypeList	An array of the vehicle types from the Vehicles tab

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Section 2 – General Structure Information

The data input in this section is used to determine the applicable failure mechanisms, dead loads, and structure condition.

ITEM	VARIABLE	DESCRIPTION																		
Span length	Span	Length between springlines, obtained from the Start and CT-Fill Program																		
Rise of pipe	Rise	Total height of pipe																		
Height of springline	SpringLine	Vertical distance from the bottom of the structure to the springline																		
Pipe type	Pipe_Type	The pipe types supported by this worksheet are the following: <table border="1"> <tr> <td>1</td><td>Corrugated Plates</td><td>Pipes made from corrugated plate sections bolted or riveted together to form the required shape</td></tr> <tr> <td>2</td><td>Corrugated Pipe</td><td>Pipes made from continuous corrugated sheets or with edges joined by welds or lockseams.</td></tr> <tr> <td>3</td><td>Spiral Pipe</td><td>Pipes made from continuous corrugated sheets with external spiral ribs</td></tr> </table>	1	Corrugated Plates	Pipes made from corrugated plate sections bolted or riveted together to form the required shape	2	Corrugated Pipe	Pipes made from continuous corrugated sheets or with edges joined by welds or lockseams.	3	Spiral Pipe	Pipes made from continuous corrugated sheets with external spiral ribs									
1	Corrugated Plates	Pipes made from corrugated plate sections bolted or riveted together to form the required shape																		
2	Corrugated Pipe	Pipes made from continuous corrugated sheets or with edges joined by welds or lockseams.																		
3	Spiral Pipe	Pipes made from continuous corrugated sheets with external spiral ribs																		
Pipe shape	Pipe	The pipe shapes supported by this worksheet are the following: <table border="1"> <tr> <td>1</td><td>Round</td><td>Round </td></tr> <tr> <td>2</td><td>Arch</td><td>Arch </td></tr> <tr> <td>3</td><td>Pipe Arch</td><td>Pipe Arch </td></tr> <tr> <td>4</td><td>Underpass</td><td>Underpass* </td></tr> <tr> <td>5</td><td>Low Profile Arch</td><td>Low Profile Arch </td></tr> <tr> <td>6</td><td>High Profile Arch</td><td>High Profile Arch </td></tr> </table>	1	Round	Round 	2	Arch	Arch 	3	Pipe Arch	Pipe Arch 	4	Underpass	Underpass* 	5	Low Profile Arch	Low Profile Arch 	6	High Profile Arch	High Profile Arch 
1	Round	Round 																		
2	Arch	Arch 																		
3	Pipe Arch	Pipe Arch 																		
4	Underpass	Underpass* 																		
5	Low Profile Arch	Low Profile Arch 																		
6	High Profile Arch	High Profile Arch 																		
Pipe material	Material	The pipe materials supported by this worksheet are the following: <table border="1"> <thead> <tr> <th></th><th>Material</th><th>Modulus of Elasticity E_{pipe}, (ksi)</th><th>Unit Weight ϕ_{pipe}, (pcf)</th></tr> </thead> <tbody> <tr> <td>1</td><td>Steel</td><td>29000</td><td>490</td></tr> <tr> <td>2</td><td>Aluminum</td><td>10000</td><td>175</td></tr> </tbody> </table>		Material	Modulus of Elasticity E_{pipe} , (ksi)	Unit Weight ϕ_{pipe} , (pcf)	1	Steel	29000	490	2	Aluminum	10000	175						
	Material	Modulus of Elasticity E_{pipe} , (ksi)	Unit Weight ϕ_{pipe} , (pcf)																	
1	Steel	29000	490																	
2	Aluminum	10000	175																	
Pipe seams present	Seam	The options for this variable are: <table border="1"> <tr> <td>1</td><td>Yes</td><td>Corrugated plate sections bolted or riveted together to form the required shape</td></tr> <tr> <td>2</td><td>No</td><td>Continuous corrugated sheets or with edges joined by welds or lockseams</td></tr> </table>	1	Yes	Corrugated plate sections bolted or riveted together to form the required shape	2	No	Continuous corrugated sheets or with edges joined by welds or lockseams												
1	Yes	Corrugated plate sections bolted or riveted together to form the required shape																		
2	No	Continuous corrugated sheets or with edges joined by welds or lockseams																		
Condition factor	ϕ_c	Condition factor for section being considered during the analysis																		
System factor	ϕ_s	Default value $\rightarrow \phi_s = 1.0$																		

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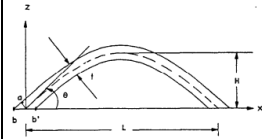
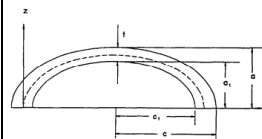
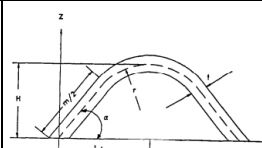
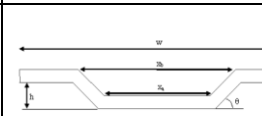
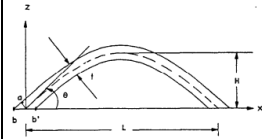
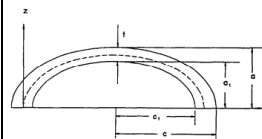
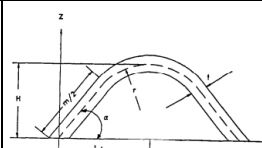
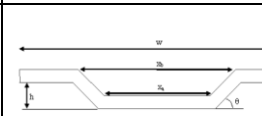
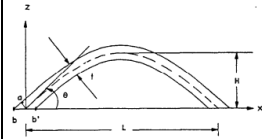
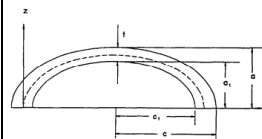
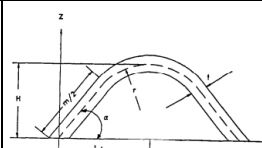
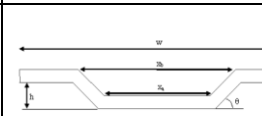
Section 2.1 – Permanent Loads and Load Factors

The data input in this section defines typical load factors and provides the user the option to consider additional dead loads on the structure during the analysis.

ITEM	VARIABLE	DESCRIPTION
Load factor for structural components	γ_{DC1}	Default value $\rightarrow \gamma_{DC1} = 1.25$
Load factor for nonstructural attachments	γ_{DC2}	Default value $\rightarrow \gamma_{DC2} = 1.25$
Load factor for additional user defined load	γ_A	Load factor for optional additional user-defined load
Unfactored DC2 load	L_{DC2}	Optional unfactored DC2 load Default value $\rightarrow L_{DC2} = \text{NaN}$
Unfactored additional load	$L_{\text{additional}}$	Optional unfactored additional load Default value $\rightarrow L_{\text{additional}} = \text{NaN}$

Section 3 – Pipe Properties

The data input in this section defines the strength, geometry, and corrugation properties of the pipe.

ITEM	VARIABLE	DESCRIPTION															
Ultimate strength	F_u	Ultimate strength of steel															
Yield strength	F_y	Steel yield strength															
Pipe Thickness	Pipe_Thickness	The options for this variable are: <table border="1"> <tr> <td>1</td> <td>Yes</td> <td>Corrugation thickness varies between the crown, corner, and bottom.</td> </tr> <tr> <td>2</td> <td>No</td> <td>Corrugation thickness does not vary between the crown, corner, or bottom. Program will assume all radii have the same corrugation thickness as input for the crown location (T_{crown}).</td> </tr> </table> Not applicable for the following: Pipe = 2	1	Yes	Corrugation thickness varies between the crown, corner, and bottom.	2	No	Corrugation thickness does not vary between the crown, corner, or bottom. Program will assume all radii have the same corrugation thickness as input for the crown location (T_{crown}).									
1	Yes	Corrugation thickness varies between the crown, corner, and bottom.															
2	No	Corrugation thickness does not vary between the crown, corner, or bottom. Program will assume all radii have the same corrugation thickness as input for the crown location (T_{crown}).															
Corrugation type	Corrugation	The corrugation types supported by this worksheet are the following: <table border="1"> <tr> <td>1</td> <td>Sinusoidal</td> <td></td> </tr> <tr> <td>2</td> <td>Semi-Elliptical</td> <td></td> </tr> <tr> <td>3</td> <td>Arc-and-Tangent (Annular)</td> <td></td> </tr> <tr> <td>4</td> <td>Trapezoidal</td> <td></td> </tr> <tr> <td>5</td> <td>User Defined</td> <td>Corrugation properties are known or calculated by the user</td> </tr> </table> Default value $\rightarrow$ Corrugation = 5	1	Sinusoidal		2	Semi-Elliptical		3	Arc-and-Tangent (Annular)		4	Trapezoidal		5	User Defined	Corrugation properties are known or calculated by the user
1	Sinusoidal																
2	Semi-Elliptical																
3	Arc-and-Tangent (Annular)																
4	Trapezoidal																
5	User Defined	Corrugation properties are known or calculated by the user															

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Section 3.1 – Properties at Crown Radius

ITEM	VARIABLE	DESCRIPTION
Crown radius	Radius _{crown}	Radius of pipe at the crown
Crown corrugation thickness	T _{crown}	Thickness of the corrugation at the crown of the pipe
Crown seam strength	F _{crown}	Seam strength of the corrugation at the crown of the pipe <u>Not</u> applicable for the following: Seam = 2

Section 3.2 – Properties at Side Radius

The orange text box will prompt the user to “Expand this section” if user inputs are required for the analysis. This section is applicable for Pipe = 4 and Pipe = 5.

ITEM	VARIABLE	DESCRIPTION
Side radius	Radius _{side}	Radius of pipe at the side
Side corrugation thickness	T _{side}	Thickness of the corrugation at the side of the pipe <u>Not</u> applicable for the following: Pipe_Thickness = 2
Side seam strength	F _{side}	Seam strength of the corrugation at the side of the pipe <u>Not</u> applicable for the following: Seam = 2

Section 3.3 – Properties at Corner Radius

The orange text box will prompt the user to “Expand this section” if user inputs are required for the analysis.

ITEM	VARIABLE	DESCRIPTION
Corner radius	Radius _{corner}	Radius of pipe at the corner <u>Not</u> applicable for the following: - Pipe_Type = 1 - Pipe_Type = 2 - Pipe_Type = 5
Corner corrugation thickness	T _{corner}	Thickness of the corrugation at the corner of the pipe <u>Not</u> applicable for the following: Pipe_Thickness = 2
Corner seam strength	F _{corner}	Seam strength of the corrugation at the corner of the pipe <u>Not</u> applicable for the following: Seam = 2

Section 3.4 – Properties at Low Side Radius

The orange text box will prompt the user to “Expand this section” if user inputs are required for the analysis. This section is applicable for Pipe = 6.

ITEM	VARIABLE	DESCRIPTION
Side radius	Radius _{lowside}	Radius of pipe at the side
Side corrugation thickness	T _{lowside}	Thickness of the corrugation at the side of the pipe <u>Not</u> applicable for the following: Pipe_Thickness = 2
Side seam strength	F _{lowside}	Seam strength of the corrugation at the side of the pipe <u>Not</u> applicable for the following: Seam = 2

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Section 3.5 – Properties at Bottom Radius

The orange text box will prompt the user to “Expand this section” if user inputs are required for the analysis.

ITEM	VARIABLE	DESCRIPTION
Bottom radius	Radius _{bottom}	Radius of pipe at the bottom <u>Not</u> applicable for the following: • Pipe_Type = 1 • Pipe_Type = 2 • Pipe_Type = 5
Bottom corrugation thickness	T _{bottom}	Thickness of the corrugation at the bottom of the pipe <u>Not</u> applicable for the following: • Pipe_Thickness = 2
Seam strength	F _{bottom}	Seam strength of the corrugation at the bottom of the pipe <u>Not</u> applicable for the following: • Seam = 2

Section 4 – Corrugation

This section is used to define corrugation properties along the pipe section.

ITEM	VARIABLE	DESCRIPTION
Corrugation pitch	Pitch	Distance of corrugations from crest to crest
Corrugation depth	Depth	Total depth of corrugation from top crest to bottom crest

Section 4.1 – Arc-and-Tangent (Annular) Corrugation Type

The orange text box will prompt the user to “Expand this section” if user inputs are required for the analysis. This section is only applicable for Corrugation_Type = 3

ITEM	VARIABLE	DESCRIPTION
Corrugation radius	r	Radius of corrugation based on corrugation size (pitch and depth)

Section 4.2 – Trapezoidal Corrugation Type

The orange text box will prompt the user to “Expand this section” if user inputs are required for the analysis. This section is only applicable for Corrugation_Type = 4

ITEM	VARIABLE	DESCRIPTION
Acute trapezoidal angle	θ	The acute angle for the trapezoidal corrugation $\theta < 90^\circ$

Section 4.3 – User Defined Corrugation Type

The orange text box will prompt the user to “Expand this section” if user inputs are required for the analysis. This section is only applicable for Corrugation_Type = 5

ITEM	VARIABLE	DESCRIPTION
Moment of inertia	I_{crown}	The moment of inertia for the corrugation at the crown of the pipe
	I_{side}	The moment of inertia for the corrugation at the side of the pipe
	I_{corner}	The moment of inertia for the corrugation at the corner of the pipe
	I_{lowside}	The moment of inertia for the corrugation at the low side of the pipe
	I_{bottom}	The moment of inertia for the corrugation at the bottom of the pipe
Area of section	A_{crown}	The area of section for the corrugation at the crown of the pipe
	A_{side}	The area of section for the corrugation at the side of the pipe
	A_{corner}	The area of section for the corrugation at the corner of the pipe
	A_{lowside}	The area of section for the corrugation at the low side of the pipe
	A_{bottom}	The area of section for the corrugation at the bottom of the pipe
Radius of gyration	r_{crown}	The radius of gyration for the corrugation at the crown of the pipe
	r_{side}	The radius of gyration for the corrugation at the side of the pipe
	r_{corner}	The radius of gyration for the corrugation at the corner of the pipe
	r_{lowside}	The radius of gyration for the corrugation at the low side of the pipe
	r_{bottom}	The radius of gyration for the corrugation at the bottom of the pipe

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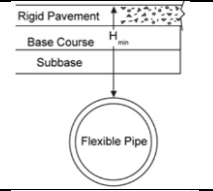
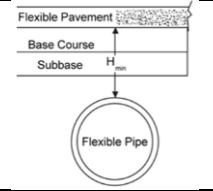
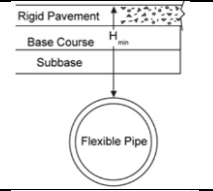
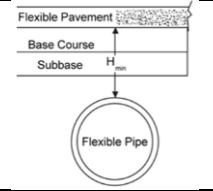
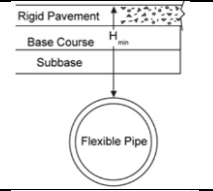
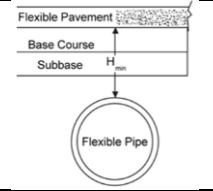
Section 4.5 – Corrugation Properties Summary

This section provides a summary of the corrugation properties.

ITEM	VARIABLE	DESCRIPTION
Moment of inertia	I_c	Array of the moment of inertia for the corrugation at the: • Crown • Side • Corner • Low Side • Bottom
Area of section	A_c	Array of the area of section for the corrugation at the: • Crown • Side • Corner • Low Side • Bottom
Radius of gyration	r_c	Array of the radius of gyration for the corrugation at the: • Crown • Side • Corner • Low Side • Bottom

Section 5 – Pavement Properties

The data input in this section defines the pavement type and properties to determine load.

ITEM	VARIABLE	DESCRIPTION						
Pavement flexibility	Pavement_Type	The options for this variable are: <table border="1"> <tr> <td>1</td><td>Rigid Pavement</td><td>  </td></tr> <tr> <td>2</td><td>Flexible Pavement</td><td>  </td></tr> </table>	1	Rigid Pavement		2	Flexible Pavement	
1	Rigid Pavement							
2	Flexible Pavement							
Wearing surface thickness	$t_{\text{wearing_surface}}$	Thickness of rigid or flexible pavement						
Load factor for wearing surface	γ_{DW}	Default value $\rightarrow \gamma_{DW} = 1.50$						
Wearing surface unit weight	δ_{ws}	Default value $\rightarrow \delta_{ws} = 155 \text{ pcf}$						

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Section 6 – Structure Considerations

This section provides structure conditions, based on the previous inputs, which are used to determine the minimum depth of fill and the failure mechanisms to consider during analysis.

ITEM	VARIABLE	DESCRIPTION
Determine if structure qualifies as a 'Long-Span' structure	IsLongSpan	*BDS Article 12.8.1
Determine if the structure contains 'Deep Corrugations'	DeepCorrugation	*BDS Article 12.2 for the definition of 'Deep Corrugated Plate'

Section 7 – Soil Properties

The data input in this section defines the soil properties and load factors.

ITEM	VARIABLE	DESCRIPTION
Depth of fill over top of pipe	H_{fill}	Height of cover above the crown of the pipe (including pavement)
Depth of water table above the springline	H_w	Input used to consider hydrostatic pressure at the springline of the pipe *BDS Article 12.12.3.8
Soil unit weight	δ_{soil}	Default value $\rightarrow \delta_{soil} = 125 \text{ pcf}$
Load factor for vertical earth pressure	γ_{EV}	Default value $\rightarrow \gamma_{EV} = 1.95$
Soil stiffness factor	k	Default value $\rightarrow k = 0.22$
Factor for uncertainty in level of groundwater table	K_{wa}	Default value $\rightarrow K_{wa} = 1.3$
Load factor for hydrostatic pressure	γ_{WA}	Default value $\rightarrow \gamma_{WA} = 1.0$
Coefficient to account for variation of thrust around the circumference	K_{2_crown}	Default value $\rightarrow K_{2_crown} = 0.6$
	$K_{2_springline}$	Default value $\rightarrow K_{2_springline} = 1.0$
Height of Cover is AASHTO Compliant		Determines if the depth of fill over the top of the pipe meets the minimum cover requirements in BDS Article 12.6.6.3
Depth of Fill is AASHTO Compliant		Determines if live load distribution through fill meets the requirements in BDS Article 3.6.1.2.6a
Minimum depth of fill considered in analysis	H_{min}	Minimum depth of fill input in the CT-MPipe_Start file and subsequently to compute live load through fill in CT-Fill
Maximum depth of fill considered in analysis	H_{max}	Maximum depth of fill input in the CT-MPipe_Start file and subsequently to compute live load through fill in CT-Fill

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Section 7.1 – Secant Constrained Soil Modulus

This section pertains to the secant constrained soil modulus, M_s , used when considering global buckling for deep corrugated structures and the hoop stiffness factor, S_H , used when computing live load. The worksheet is capable of determining M_s if the soil compaction level, C , and the soil type are defined. The worksheet uses BDS Table 12.13.3.1-1 to determine M_s , based on the soil type, compaction level, and the free field vertical stress at a depth halfway between the top and springline of the structure.

ITEM	VARIABLE	DESCRIPTION										
Soil type	Soil_Type	Soil types supported to calculate the secant constrained soil modulus: <table><tr><td>SN</td><td>Gravelly Sand</td></tr><tr><td>SI</td><td>Sandy Silt</td></tr><tr><td>CL</td><td>Silty Clay</td></tr><tr><td>CB</td><td>Compact Crushed Stone Pervious Backfill SN-100 (Gravelly Sand at 100% compaction) *BDS Article C12.12.3.5</td></tr><tr><td>UB</td><td>Uncompact Crushed Stone Pervious Backfill SN-90 (Gravelly Sand at 90% compaction) *BDS Article C12.12.3.5</td></tr></table>	SN	Gravelly Sand	SI	Sandy Silt	CL	Silty Clay	CB	Compact Crushed Stone Pervious Backfill SN-100 (Gravelly Sand at 100% compaction) *BDS Article C12.12.3.5	UB	Uncompact Crushed Stone Pervious Backfill SN-90 (Gravelly Sand at 90% compaction) *BDS Article C12.12.3.5
SN	Gravelly Sand											
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UB	Uncompact Crushed Stone Pervious Backfill SN-90 (Gravelly Sand at 90% compaction) *BDS Article C12.12.3.5											
Scalar calibration factor	C _n	Scalar calibration factor to account for some nonlinear effects Default value → C _n = 0.55 *BDS Article 12.8.9.6										
Soil compaction level	C	Soil compaction level options: - For "SN", C = $\begin{cases} 85\% \\ 90\% \\ 95\% \\ 100\% \end{cases}$ - For "SI", C = $\begin{cases} 85\% \\ 90\% \\ 95\% \end{cases}$ - For "CB", C = $\begin{cases} 85\% \\ 90\% \\ 95\% \end{cases}$										
Poisson's ratio of soil	v	Default value → v = 0.4										
User-defined secant constrained soil modulus	M _{s_user}	Default value → M _{s_user} = NaN										

Section 8 – Resistance Factors

This section contains functions that determine the Resistance Factors, in accordance with BDS Table 12.5.5-1, based on the structure type.

ITEM	VARIABLE	DESCRIPTION
Wall yield strength	ϕ_{wall}	Resistance factor for axial resistance
Buckling	ϕ_{bkl}	Resistance factor for buckling resistance
Seam	ϕ_{seam}	Resistance factor for seam strength
General buckling	ϕ_b	Resistance factor for general buckling Only applicable for the following: DeepCorrugation = "Yes"
Soil	ϕ_{soil}	Resistance factor for soil Only applicable for the following: DeepCorrugation = "Yes"

Section 9 – Dead Load

This section calculates the pressure loads on the structure.

Section 9.1 – Soil-Prism Pressure

This section considers soil-prism pressure, as defined in BDS Article 12.12.3.7, when calculating the soil pressure at the crown of the pipe. When compared to the free-field soil pressure calculation ($H_{fill} * \delta_{soil}$), the soil-prism pressure calculation is conservative when compared to the free-field pressure calculation. This calculation for soil-prism pressure does not considered the effects of buoyancy.

ITEM	VARIABLE	DESCRIPTION
Soil-prism pressure	P_{ps}	Soil pressure at the crown of the pipe *BLRM Article 10.6.3

Section 9.2 – Hydrostatic Pressure

This section calculates the hydrostatic pressure in accordance with BDS Article 12.12.3.8. The inclusion of hydrostatic pressure within the load rating analysis is not required, but may be considered at the discretion of the LRE.

ITEM	VARIABLE	DESCRIPTION
Hydrostatic water pressure	P_w	Hydrostatic water pressure at the springline of the pipe <u>Not</u> applicable if $H_w = 0$ ft

Section 9.3 – Self-Weight Pressure

This section calculates the self-weight pressure of the pipe.

ITEM	VARIABLE	DESCRIPTION
Self-weight pressure	P_{self_weight}	Self-weight pressure due to the crown of the pipe.

Section 9.4 – Wearing Surface Pressure

This section calculates the pressure on the crown of the pipe due to the wearing surface.

ITEM	VARIABLE	DESCRIPTION
Wearing surface pressure	$P_{wearing_surface}$	Self-weight pressure due to the crown of the pipe.

Section 10 – Dead Load

This section calculates the total factored dead load pressure and thrust applied to the structure. To view the verbose factored dead load results, access the CT-MPipe Results file. Please note that the CT-MPipe Results file cannot update while the Mathcad worksheet is open.

Section 11 – Live Load

This section calculates the total factored live load pressure and thrust applied to the structure. To view the verbose factored live load results, access the CT-MPipe Results file. Please note that the CT-MPipe Results file cannot update while the Mathcad worksheet is open.

Section 12 – Capacity

This section calculates the resistances and capacities of the structure.

Section 13 – Detailed Rating Factors

This section computes rating factor for each combination of fill height, vehicles, and location. To view the verbose rating factor results, access the CT-MPipe Results file. Please note that the CT-MPipe Results file cannot update while the Mathcad worksheet is open.

Section 14 – Rating Factor Summary

This section contains an array, which provides the user with the controlling rating factor and corresponding location and failure mechanism for each vehicle. To view the controlling rating factor results, access the CT-MPipe Results file. Please note that the CT-MPipe Results file cannot update while the Mathcad worksheet is open.